Space Charge Distortions in the STAR TPC

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A track in the TPC is the result of a trail of secondary electrons that lie along the path of the primary particle. A trail of positive ions also lie along the path of the primary particle but the mobility of the positive ions is very low and they drift 1000 times more slowly than the electrons. Thus, the residual space charge from the ions will distort tracks in subsequent events.

We have observed this effect in the STAR TPC and we correct the data, event by event, for the effect of the positive ion space charge build up[1]. We assume that the majority of the space charge is created by upstream events inside the accelerator and the positive ions are initially uniformly distributed in the TPC. The final space charge distribution is a triangle function, in Z, because the charges drift towards the CM and integrated over a mean residence time in the TPC.

The electric field due to the space charge build up is given in the following equation:

$$E_r = \frac{-4C}{L} \sum_{n=1}^{\infty} -1^{n+1} \frac{I_1(kr)[K_0(kb)-K_0(ka)]+K_1(kr)[I_0(kb)-I_0(ka)]}{K_0(kb)I_0(ka)-K_0(ka)I_0(kb)} \frac{\sin(kL-kz)}{k^2}$$

And the distortion it causes is:

$$\delta_r = \frac{-4C}{L|\vec{E}|} \sum_{n=1}^{\infty} -1^{n+1} \frac{I_1(kr)[K_0(kb)-K_0(ka)]+K_1(kr)[I_0(kb)-I_0(ka)]}{K_0(kb)I_0(ka)-K_0(ka)I_0(kb)} \frac{1-\cos(kL-kz)}{k^3}$$

C is a fitting parameter that represents the space charge in the TPC. We assume that it is proportional to the count rate in the central trigger barrel counters (CTB). L is the distance from the CM to an endcap, **E** is the electric field inside the TPC, *a* and *b* are the radii of the inner and outer field cages, respectively, k = nπ/L, and **I** and **K** are modified Bessel Functions.

The distortion causes the tracks to go "out of focus" at the event vertex but, in contrast to the IFC shift error, it is symmetric around the CM. The distortion creates a distance of closest approach error (DCA) for each track and the DCA can be measured and compared to the model. See figures one and two.

Footnotes and References

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1. Blum and Rolandi, "Particle Detection with Drift Chambers", Springer-Verlag, 1994.
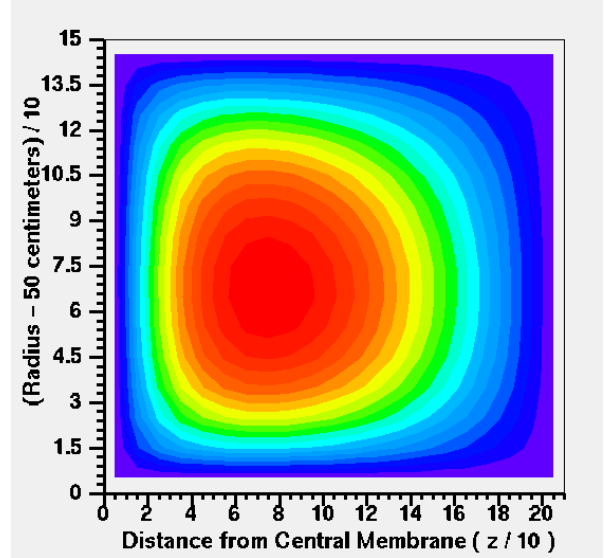

Fig. 1. The voltage pattern associated with the space charge build up in the TPC. One quadrant of the TPC volume is shown in (R,Z) coordinates.
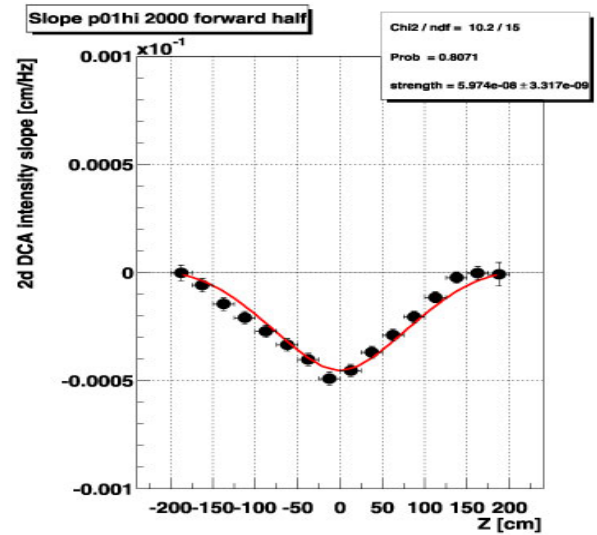

Fig. 2. The DCA of tracks near the vertex follow the trend of the model. The space charge in the TPC is estimated using CTB counts.